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SHUCK PROTECTION FOR EAR CORN.

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INTRODUCTION.

Most corn growers fail to realize that by improving the shuck covering on their corn by selection they may reduce the amount of damage done to the grain. Growers generally consider nothing but the ears and kernels when selecting seed. In weevil-infested sections in particular, variation in the damage of ears is frequently observed, but if the matter is considered the cause is usually attributed to variation in the hardness of the grain. Weevils attack corn of all degrees of hardness, and their progress in consuming the hard corn is only slower than that in the soft corn. Some observers have concluded that since weevils are able to eat the hardest corn, they would also cut their way through the most resistant shucks in order to feed upon the grain, if sufficiently urged by hunger. Others have observed that earworms may cut holes through a large percentage of the protecting shucks and that weevils will enter through these holes, and they have concluded from this that shuck covering can not be made a practicable means of protection. Then, too, there is a sentiment on the part of some against a large amount of shuck.

With such a formidable array of misconceptions and real difficulties as these and others, it is not surprising that little or no action

is being taken in the matter to bring about practical results. This is especially true in view of the fact that very little experimental work has been done to determine the relationship that really exists between shucks and the corn inclosed by them. However, some reassuring observations in this connection have been recorded by W. E. Hinds, entomologist of the Alabama Argicultural Experiment Station.[1] Below are given certain significant quotations:

> The earliest maturing corn—almost regardless of variety—attracts them [weevils] in greatest number and naturally the ears that have exposed tips and loose, open husks are then the first and most heavily attacked. * * * But naturally the corn from the outer edges of the field and the poorly covered ears throughout the field will always contain more weevils than any other equal number of ears. * * * The two most important factors in producing this [weevil infestation] variation [of varieties] are generally comparative rapidity of development to maturity of the grain and the relative length and tightness of the husk covering. * * * From our study of these varieties, we have become convinced that weevil resistance depends first of all upon the length and tightness of the husk covering upon the maturing ear. * * * Long husks can be bred by selection in any variety. * * * Good husk covering and proper storage methods may entirely prevent the necessity for fumigation treatment.

In the following pages are given the results of investigations whose object has been to establish definitely by positive means some of the more important facts regarding the merits of shucks as a means of preventing ear damage.

RELATION OF SHUCK CHARACTERS TO INSECT INFESTATION.

FIELD INVESTIGATIONS.

The field investigations described in this bulletin were conducted during the period from September 27 to October 4, 1915. The experimental corn had been planted on March 22 and 23 at Thomasville, Ga., and was among the first planted in the community that year. At the time the data were collected the moisture in the grain varied with the variety from 12.5 to 15 per cent.

Fourteen native southern varieties were included in the investigations. They were grown in adjacent rows and harvested and studied separately, but for the purposes of this bulletin the results are considered collectively.

The ears were harvested with all of the shucks in place. They were then separated into three classes, termed "poor shucks," "good shucks without wormholes," and "good shucks with wormholes."

Ears were classified as having poor shucks if the shucks failed to extend beyond the tip of the ear or if extending beyond the tip they did not close tightly and seemed to offer opportunity for insects to enter along the passage used by the silks.

[1] Hinds, W. E. Reducing insect injury to seed corn. Ala. Agr. Exp. Sta. Bul. 176, p. 49–68, 4 pl. 1914.

Ears were classified as having good shucks if the shucks extended beyond the tip of the ear and closed more or less tightly about the silks. Most of the so-called good shucks were not ideal or such as would be the breeder's aim, but were only better than those classed as poor shucks.

If a hole or holes had been cut through a good shuck by a worm, the ear was put in the class of good shucks with wormholes; if no such openings had been made, the ear was classified as good shucks without wormholes. Only such wormholes as were cut through the shucks were considered. It was found, after removing the shucks, that some of the ears in the class good shucks without wormholes had been attacked by worms, too. They had entered through the silk channel and had either left through the same channel or died.

While the shucks were being removed an examination was made for the work of the earworm and for insect infestation, mold, and discoloration. The number of ears infested with insects or damaged by molds and discoloration was thus determined for each class of shuck covering.

At the time the notes were taken the earworms (*Heliothis obsoleta* Fab.) had completed their work. The black weevils (fig. 1) and a group composed of two or more species of small reddish brown beetles (fig. 2) were practically all the insects which infested the ears at that time. In this bulletin the black weevils are therefore termed "weevils" and the small reddish brown beetles are termed "beetles."

In making counts an ear was considered infested when only a single insect was found inside the shuck covering.

Practically without exception ears infested with weevils were also infested with beetles. For this reason the number of ears infested with beetles is the same as the total number of ears infested with insects.

The results of the investigations of the relation of the shuck covering to insect infestation are summarized in Table I.

TABLE I.—*Relation of the shuck covering of corn to insect infestation in the field.*

Kind of shuck covering.	Percentage of ears—		
	In each class of shucks.	Infested with—	
		Weevils.	Beetles.
Poor	48	52	96
Good, with wormholes	28	38	93
Good, without wormholes	25	9	56
Total		38	85

The total number of ears examined was 1,949. Of these, 48 per cent were in poor shucks, 28 per cent in good shucks with wormholes, and 25 per cent in good shucks without wormholes.

Of the ears in poor shucks, 52 per cent were infested with weevils and 96 per cent with beetles. Of the ears in good shucks with wormholes, 38 per cent were infested with weevils and 93 per cent with beetles. Of the ears in good shucks without wormholes, 9 per cent were infested with weevils and 56 per cent with beetles.

FIG. 1.—Black weevils (*Calandra oryza*), termed "weevils" in this bulletin.

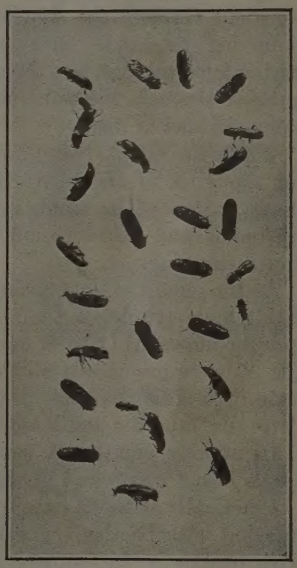

FIG. 2.—Species of small reddish brown insects, termed "beetles" in this bulletin.

A comparison of the classes with different shuck coverings shows 43 per cent more weevil infestation and 40 per cent more beetle infestation in poor shucks than in good shucks without wormholes. The wormholes through what was otherwise good shuck coverings permitted increased infestation amounting to 29 per cent for weevils and 37 per cent for beetles.

Thirty-eight per cent of all the ears examined were infested with weevils and 85 per cent with beetles. From the standpoint of infestation the beetles were the most serious of the two classes of insects; however, close examination failed to discover any damage

that could be definitely attributed to them. As there was abundant evidence of damage due to the weevils, it was concluded that so far as these two classes of insects were concerned the weevils, though greatly outnumbered by the beetles, had undoubtedly done most of the actual damage to the grain.

STORAGE INVESTIGATIONS.

Representative ears in their shucks were taken from the plat in which the field investigations were made and stored in a tight galvanized-iron bin. In August, 1916, or about 10 months after the corn was first stored, the ears were classified in accordance with the kind of shuck covering found and then carefully examined for insect infestation.

Table II shows the relation of the shuck covering to the percentage of ears infested with weevils and beetles.

TABLE II.—*Relation of the shuck covering of corn to insect infestation after 10 months in storage.*

Kind of shuck covering.	Percentage of ears—		
	Infested with—		Not infested.
	Weevils.	Beetles.	
Poor	97	100	.....
Good, with wormholes	55	100	.....
Good, without wormholes	4	77	23
Total	66	95	5

A total of 206 ears was examined. Of the ears in poor shucks, 97 per cent were infested with weevils (Pl. I) and 100 per cent with beetles, none being free from infestation. Of the ears in good shucks with wormholes, 55 per cent were infested with weevils and 100 per cent with beetles, while none was free from infestation. Of the ears in good shucks without wormholes, 4 per cent were infested with weevils and 77 per cent with beetles, 23 per cent being free from all infestation (Pl. II).

A comparison of the classes with different shuck coverings showed 93 per cent more weevil infestation and 23 per cent more beetle infestation in poor shucks than in good shucks without wormholes. The wormholes through what was otherwise good shuck coverings permitted increased infestation amounting to 51 per cent for weevils and 23 per cent for beetles.

In this, as in the field investigations, it was found that beetles infested many more ears than the weevils. If they were a factor in damaging ear corn of adapted varieties, the shuck covering would be

much less important as a means of protection. Fortunately, this did not appear to be the case, as is shown by the data given in Table III.

TABLE III.—*Relative amount of damage done to corn by weevils and by beetles.*

Infestation.	Total number of ears.	Percentage of—	
		Ears with damaged kernels.	Damaged kernels.
Weevils and beetles together	135	100	60 to 75
Beetles alone	60	5	Trace.

From 60 to 75 per cent of all the kernels on the 135 ears infested with weevils and beetles together were seriously damaged. Of the 60 ears infested with beetles alone, 5 per cent were damaged by something. It is possible that worms or other insects not present at the time of the examination might have been the cause of this damage. At any rate the damage amounted to a mere trace on 11 kernels. It is evident, therefore, that the beetles when alone were of no practical importance in the corn studied. The 11 kernels whose damage is in question were softer than most of those in the varieties used in these studies. If the beetles did this damage, then it is probable that they did so because the comparative softness made it possible. Other investigations have shown that some of the comparatively soft-grain varieties of corn from outside the areas that are badly infested with grain insects may be directly damaged by beetles. This again suggests that kernel density may determine whether direct damage from beetles is possible, and emphasizes the importance of using adapted corn which may involve protective factors that have not yet been clearly recognized. Because of the importance of adapted varieties for practical purposes this publication is confined to the results with such varieties, and since the beetles were not an important damaging factor in this connection, these insects are not further considered here.

The lots of corn considered in Tables I and II were grown in the same plat and harvested at the same time, and were as comparable as it is possible for two lots of ears to be under similar circumstances. As the lot considered in Table I was examined for infestation at harvest time (October, 1915), and the lot considered in Table II was examined for infestation after about 10 months in storage (August, 1916), the differences between the percentages of infestation found at the time of examination should represent the gain in infestation during storage. The percentages of weevil infestation shown in Tables I and II are compared in Table IV.

TABLE IV.—*Relation of the shuck covering of corn to the increase in weevil infestation during storage.*

Kind of shuck covering.	Percentage of ears infested.		Increase or decrease during storage.
	October, 1915.	August, 1916.	
Poor	52	97	45
Good, with wormholes	38	55	17
Good, without wormholes	9	4	− 5

Of the ears in poor shucks, 52 per cent were infested in 1915 and 97 per cent in 1916. The infestation in 1916 was 45 per cent greater than in 1915. Of the ears in good shucks with wormholes, 38 per cent were infested in 1915 and 55 per cent in 1916. The infestation in 1916 was 17 per cent greater than in 1915. Of the ears in good shucks without wormholes, 9 per cent were infested in 1915 and 4 per cent in 1916. The infestation in 1916 was 5 per cent less than in 1915.

It seems a significant fact that during the period of storage the percentage of weevil-infested ears increased decidedly in poor shucks and in good shucks with wormholes, but there was no increase in the percentage of ears infested in good shucks without wormholes. These data, coupled with the fact that no evidence could be found showing that weevils attempt to cut the shucks, indicate that the right kind of shuck covering is an effective barrier to this class of insects.

LABORATORY INVESTIGATIONS.

It is probable that the insects in seeking their food follow the line of least resistence. Under ordinary field and storage conditions they naturally attack the ears with least protection first and successively attack those with greater protection as the demand for food increases. While the investigations discussed on the preceding pages show that the better class of shuck protection successfully resisted insect damage under existing conditions, it is natural to suppose that insects which can eat the hardest kernels (fig. 3) of corn would also cut their way through the protecting shucks if sufficiently urged by hunger. With ordinary field and storage conditions it has always been possible for weevils to find some food, and for this reason it was not necessary to force a way to the corn in the best shucks in order that they might avoid extinction. With complete success in the breeding of ideal shuck coverings this last condition might arise, and it is desirable to know whether the acquired shuck coverings would prevent infestation under such conditions. To determine this point a number of weevils were confined in properly ventilated jars with ears of corn in good shuck coverings, but with no other source of food. The test was

begun in August, while the temperature was high and the weevils very active. By the following December all the weevils were dead and dry, none had reached the grain, and no evidence could be found that they had attempted to force their way through the shuck protection to the grain.

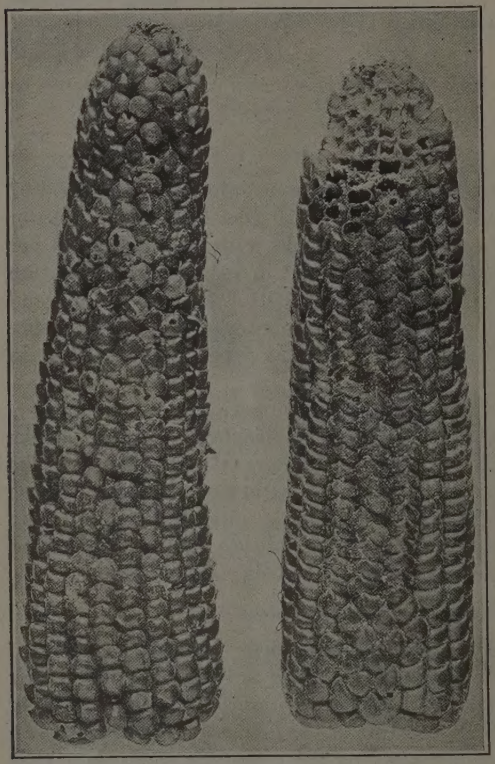

FIG. 3.—White Rice pop corn damaged by weevils. These insects can eat the hardest corn.

As a logical part of this test, some weevils were confined in jars with ears of corn from which the shucks had been removed. This part of the test was identical with the first, with the exception that in this case there was no shuck protection. With four or five exceptions, the weevils were alive at the final examination and had done a very serious amount of damage to all the ears.

This test makes it evident that while it seems that these insects should be quite able to cut through all of the shuck covering that corn may have, they, in fact, will not do so, even though they must starve if they do not.

RESULTS OF INVESTIGATIONS IN 1916.

On October 6, 1916, at Thomasville, Ga., a quantity of corn was selected from a field and examined for ear damage. The variety in this case was one of those used in the 1915 investigations. As may be gathered from the data, it had a wide range of protective adaptation. As the field was located about one-fourth of a mile from places where old infested corn was stored, the opportunity for weevil infestation was very good. The worm damage is believed to have been exceptionally severe.

The ears examined were of three classes. The first class had shucks extending from 4 to 6 inches and the second class from 2 to 3 inches beyond the tips of the ears; the third class had practically no shucks extending beyond the tips of the ears. The relation of shuck covering to infestation as it was found in these classes is shown in Table V.

TABLE V.—*Relation of the shuck covering of corn to insect infestation in 1916.*

Kind of shuck covering.	Number of ears examined.	Percentage of ears—		
		Attacked by worms.	Infested with weevils.	Affected with worm mold.
Extending 4 to 6 inches beyond tips of ears	111	72	9	64
Extending 2 to 3 inches beyond tips of ears	102	87	22	77
Practically no extension	100	96	100	91

Of the 111 ears with shucks extending from 4 to 6 inches beyond the tips of the ears, 72 per cent had been attacked by worms, 9 per cent had been infested by weevils, and 64 per cent had been affected with worm mold. Of the 102 ears with shucks extending from 2 to 3 inches beyond the tips of the ears, 87 per cent had been attacked by worms, 22 per cent had been infested with weevils, and 77 per cent had been affected with worm mold. Of the 100 ears with practically no shuck extension beyond the tips of the ears, 96 per cent had been attacked by worms, 100 per cent had been infested by weevils, and 91 per cent had been affected with worm mold.

In the case of worms, 15 per cent fewer ears were attacked in the 4 to 6 inch extension shucks than in those having 2 to 3 inch extensions, and 24 per cent fewer than where there was practically no extension. There were 13 per cent fewer ears infested with weevils in the 4 to 6 inch than in the 2 to 3 inch extension shucks and 91 per cent fewer than in the shucks having practically no extension, while 13 per cent fewer ears were affected with worm mold in the 4 to 6 inch extension shucks than in the 2 to 3 inch extension shucks, and 27 per cent fewer than in those having practically no extension.

These figures make it clear that length of shuck extension is a controlling factor in the matter of ear damage. In addition, the relationship between the length of shuck extension and the percentage of ears attacked by worms is of special interest because, in connection with the following evidence, it suggests a possible means of overcoming the most serious obstacle in the way of making a perfectly effective shuck protection for practically all of the ears.

SHUCK EXTENSION AS A PREVENTIVE OF WORM DAMAGE.

The foregoing discussion has made it clear that earworms may be responsible (directly and indirectly) for much damage to corn. The fact that earworms can and sometimes do cut holes through a

large percentage of the protecting shucks would seem to be an insurmountable barrier to those who would breed for shuck protection against weevils. It has been shown (Table V), however, that the proportion of ears attacked by worms tends to decrease as the shuck extension is increased.

The earworms usually enter the shuck coverings through the silk channels, feeding on the silk as they go, the holes through the shucks being made when they are leaving. If while feeding on the silks and with its hunger not yet satisfied a worm reaches an ear which is sufficiently tender to be attractive, it may feed upon the kernels and cob for a time before cutting out. If, however, during its progress along the silk channel the silks become unpalatable on account of age or the worm reaches maturity, it may abandon its course before reaching the ear. Reasoning along this line, one naturally concludes that the longer the shuck extension or silk channel the more likely it is that worms will leave the shucks before they reach the grain. This conclusion is supported by the data presented in Table VI. The ears examined for this information were a part of those examined to obtain the information given in Table V.

TABLE VI.—*Relation of the length of shuck extension of ears of corn to the worm damage.*

Kind of shuck covering.	Total number of ears examined.	Percentage of ears not eaten because worms cut from silk channels before reaching the grain.
Extending 4 to 6 inches beyond tips of ears	111	14
Extending 2 to 3 inches beyond tips of ears	102	7
Advantage due to the longer shuck extension		7

It may be seen that of the 111 ears with shucks extending from 4 to 6 inches beyond the tips of the ears, 14 per cent had escaped damage because the worms had cut from the silk channels before reaching them. It may also be seen that of the 102 ears with shucks extending from 2 to 3 inches beyond the tips of the ears, 7 per cent had escaped damage because the worms had cut from the silk channels before reaching them.

By comparison it may be seen that the longer shuck extension afforded 7 per cent more protection than the shorter shuck extension.

These investigations, in part at least, show why shuck extension reduces the amount of worm damage. In addition, they suggest the possibility of breeding a shuck extension long enough to be entirely effective against earworms. The extent to which the earworms can be eliminated by the means suggested can only be determined by other investigations.

RELATION OF SHUCK COVERING TO MOLD AND DISCOLORATION.

The relation of shuck covering to the mold and discoloration of corn was studied in the field in connection with the investigations in 1915 of the relation of shuck covering to insect infestation. The affected ears were classed as rotten, discolored, or worm moldy.

Those ears termed "rotten" were extensively affected by molds and would have been rejected by anyone culling to improve the grade of the corn.

Those ears termed "discolored" had some kernels slightly affected by molds, stained by the shucks, checked by small cracks, or they were tarnished as though they had been soaked in water. Most of this discoloration would not have been given serious consideration by the average observer.

The ears termed "worm moldy" were such as were affected by mold that seemed to have been made possible by the attacks of earworms. These ears, because of their large number and the slight damage done, would not have been discarded by the most fastidious in an attempt to improve the grade.

As this corn was examined comparatively early in the fall, a large percentage of the stalks standing erect and the ears not shaded by vines, weeds, or other growth, and as the seasonal conditions for drying the mature ears were favorable, the proportion of damaged corn was much less than may often be seen in the section covered by these investigations.

For these investigations the ears were separated into classes with poor shucks and with good shucks. The class with good shucks includes both those with and without wormholes. In other respects the classification is the same as that for the investigations involving insects. The results of the investigations of the relation of the shuck covering to rotten, discolored, and worm-moldy ears are summarized in Table VII.

TABLE VII.—*Relation of shuck covering to the percentage of ears of corn found to be rotten, discolored, or having worm molds.*

Kind of shuck covering.	Percentage of ears—		
	Rotten.	Discolored.	Worm moldy.
Poor	4	34	58
Good	1	18	40
Total	3	27	50

A total of 1,157 ears was examined. Of the ears in poor shucks, 4 per cent were rotten, 34 per cent were discolored, and 58 per cent were affected with worm mold. Of the ears in good shucks, 1 per cent

were rotten, while 18 per cent were discolored and 40 per cent were worm moldy.

A comparison of the classes with different shuck coverings shows that 3 per cent more ears in poor shucks than in good shucks were rotten, 16 per cent more were discolored, and 18 per cent more were affected with worm mold.

GENERAL VALUE OF A GOOD SHUCK COVERING.

Of all the ears of corn produced in the United States each year, comparatively few entirely escape damage. Most of them lose only a few kernels because of earworms or other insects or are more or less reduced in value by molds or discoloration. This damage is usually passed without concern, but when it is considered that a loss of only one kernel per ear amounts to an annual loss for the United States of at least 5,000,000 bushels and that this amount must be multiplied several times to represent the total annual loss, it becomes apparent that these losses are worthy of attention. It seems that by improving the shuck protection ear damage in any section can be considerably reduced, but such protection can be made of the greatest value in sections infested with weevils. Some special advantages of shuck protection in a weevil-infested section are mentioned below.

ADVANTAGES IN THE FIELD.

The relation of the shuck covering to the percentage of damaged kernels is illustrated by the figures presented in Table VIII. These data were obtained on October 6, 1916, from two of the lots of ears considered in Table V.

TABLE VIII.—*Relation of the shuck covering of corn to the percentage of damaged kernels.*

Kind of shuck covering.	Number of ears examined.	Percentage of kernels damaged.			Total.
		By weevils.	By earworms.	By worm mold.	
With practically no extension	100	14	6	[a]4	20
With an extension of 4 to 6 inches beyond the tips of the ears	111	0	1	[a]1	1
Advantage in favor of shuck extension		14	5		19

[a] These figures are included in those for worm-eaten kernels.

With practically no shuck extension, 14 per cent of the kernels were damaged by weevils, 6 per cent by worms, and 4 per cent by worm mold. No kernels with shuck extensions of 4 to 6 inches were damaged by weevils, 1 per cent were damaged by worms, and 1 per cent by worm mold. The ears in shucks with practically no extension had a total of 20 per cent of their kernels damaged, while in the ears with shuck extensions only 1 per cent were damaged. It is evident,

therefore, that the long shuck extension effected a saving of 19 per cent in the field. This saving could not have been effected by earlier harvesting and fumigation, because the corn was taken from the field as soon as it was sufficiently dry to permit storage.

ADVANTAGES IN STORAGE.

There is some conflict of opinion regarding the matter of storing corn in the shuck. Some believe that corn stored in the shuck is more or less protected from weevils because of the shucks. Others reason that these insects enter the shucks in the field and then, being carried with the ears put in storage, they are able to continue their work of destruction. They further reason that if the shucks were removed in the field many of the insects would be left behind, and to that extent the damage would be lessened. The facts presented on the foregoing pages have shown that the right kind of shuck covering is not entered by weevils, but that poor or defective shucks may be entered. It is evident, therefore, that so far as weevil damage is concerned, the advantage or disadvantage of the method of storing corn in the shuck is determined by the kind of shuck covering on the corn stored. A certain number of ears in all varieties are exposed in the field. To store such ears in their shucks after the grain has become infested is to make conditions most favorable for the insects. To shuck them in the field is to leave a part of the insects behind, but as these ears still contain adults, larvæ, and eggs, destruction will continue, and they will remain a source from which uninfested and exposed corn may become infested.

On the other hand, there are usually some ears in varieties native to weevil-infested sections that because of their effective shuck coverings do not become infested with weevils. To store such ears in their unopened shucks is to afford them continued protection. To shuck such ears is to expose them to the attacks of insects, including the Angoumois grain moth, unless they are protected by other means. The average farmer does not use other effective means of protection, because they involve additional cost and, in the case of fumigation with carbon bisulphid, extra fire risk. Shuck protection involves no additional cost and no extra fire risk. It seems, therefore, that a storage method that utilizes shuck protection will very greatly increase the practice of holding and feeding corn on farms in weevil-infested areas. Such a method is outlined as follows: Grow the best shuck-protected corn, store the shuck-protected ears in their shucks, and feed or sell the unprotected ears as early as possible.

If there is a considerable percentage of unprotected ears, as is always the case at present, and these ears are known to be infested, they should be shucked as early as possible and kept away from uninfested corn. The shucking should be done in such a way that the dislodged insects may be swept together and burned.

ADVANTAGES IN MARKET QUALITY.

The price of corn is governed in part by its commercial grade. In order to improve the grade of corn offered on the market, growers are sometimes advised to cull the damaged ears. It is practicable to cull only such as are extensively damaged. After culling, there may be as much or more damaged corn remaining as was removed, because it is scattered through a large percentage of the ears in the form of discolored and worm-moldy kernels. It has been shown (Table VII) that shuck protection reduces both of these kinds of damage. For this reason it also makes possible a higher grade of corn than can otherwise be secured.

RELATION OF INCREASED SHUCK PROTECTION TO THE COST OF SHUCKING.

There is a noticeable variation in the amount and kind of shucks on corn grown in different sections of the United States. Whenever unshucked corn is subjected to weevil attack, the ears with poor shuck protection are more or less damaged and to that extent are eliminated from the corn to be used for seed. This, then, leaves a higher proportion of the sound corn on ears with good shuck protection. For this reason, the natural tendency, with other circumstances favorable, has been toward the use of seed from ears with good shuck protection. So, as a general rule, varieties native to weevil-infested sections have a heavier and longer shuck than those native to sections without weevils. Notwithstanding the overpowering influence of natural circumstances in weevil-infested sections and its weaker influence in other sections, there has been a general tendency on the part of corn growers toward a lighter and shorter shuck. The chief reason for this preference has been the desire to reduce the amount of hand labor required to shuck the ears.

In some varieties commonly grown in weevil-infested sections, the shuck protection can be greatly improved without producing a greater amount of shuck. This can be done by improving the shape of the present shucks by means of selection, having in view longer and closer fitting coverings. Then, too, improved machinery is now available which may be made to meet any objection to the increased quantity of shuck that is necessary to protect the ears. These machines are known as "shuck shellers" and are now commonly used by the larger grain and feed dealers in the South. Either the shucked or unshucked ears, after having been broken from the stalks, are handled by these machines. In the case of ears in the shucks, the shelled grain, the cobs, and the shucks are separated. The shucks are usually baled and sold for feed, but occasionally mattress and other factories take a part of the output. Some of the companies have received inquiries from paper manufacturers regarding the quantity

of shucks they could supply, but up to the present time there has been an insufficient quantity available to justify the paper companies in entering the market for them. Wherever such data could be obtained it was found that the amount obtained from the sale of shucks fully covered the cost of shelling and separation, and there seems to be no chance of an overproduction. It appears, therefore, that increased shuck protection need not increase the present cost of shucking.

THE PRODUCTION OF BETTER SHUCK PROTECTION.

There is abundant evidence to indicate that shuck covering responds to selection. Some of this evidence is summarized as follows: (1) Varieties native to weevil-infested sections usually have a higher percentage of ears in good shucks than do those native to sections where no weevils are found. (2) Varieties native to sections with comparatively few weevils and with poor shuck covering, after having been grown for a number of years in sections very seriously infested with weevils, were found to have as good shuck coverings and as much resistance to weevils as the average native variety. (3) The percentage of ears in good shucks has been increased by systematic selection.

All the known efforts in this line of selection have been of short duration, but they indicate that with similar methods and equal effort progress will be as rapid as that in other lines of selection.

Further investigations are required to determine all the points to be desired in the ideal shuck covering, but it is certain that the portion of the shucks that extends beyond the tips of the ears should be very long and that it should fit tightly about the silks.

The shuck covering can probably be improved in any variety, but some varieties have a greater range of shuck variation than others, and, with other qualities equally good, it would be desirable to start systematic breeding with one of these. Even in those varieties offering the greatest opportunities the ears with ideal shuck extensions are exceptionally rare. With varieties in this low state of selection it will necessarily require several years of the most exacting selection to attain uniform success. The breeder, however, should be encouraged in his efforts by the thought that while he must begin with exceptionally little, the advantage resulting from complete success will be exceptionally pronounced. Certainly the man who has labored to produce higher yields by selection should be attracted by this promising opportunity to save a part of the corn crop. It is usually impossible to prove that the breeder has increased the yielding power of his variety by selection, but the results of selection for better shuck protection are apparent to the eye.

SUMMARY.

The investigations reported upon in this bulletin had for their object the establishment by positive means of some of the most important facts regarding the merits of shucks as a means of preventing damage to ear corn.

Field investigations showed 4 per cent more weevil infestation in corn with poor shucks than in that having good shucks without wormholes.

Storage investigations showed 9 per cent more weevil infestation in corn with poor shucks than in that with good shucks without wormholes.

Laboratory investigations showed that weevils would starve rather than force their way through good shuck covering.

These investigations showed per cent more rotten, 16 per cent more discolored, and 18 per cent more worm-moldy ears in poor shucks than in good shucks.

The so-called good shucks of these investigations were not ideal, but only better than the so-called poor shucks. The later investigations made it clear that the longer the shuck extension beyond the tips of the ears, the more effective is the protection against causes of damage, including earworms. This suggests the possibility of breeding a shuck extension long enough to be entirely effective against ear damage.

Increased shuck protection need not increase the cost of shucking if proper use is made of shuck-shelling machinery.

These investigations appear to justify the following recommendations:

(1) Breed corn with a very long shuck extension that fits tightly about the silks.

(2) To better protect ear corn in the fields from weevils, earworms, molds, and discoloration, grow the best shuck-protected corn.

(3) To make practicable the more general holding and feeding of corn on farms in the weevil-infested areas, store shuck-protected ears in their shucks and feed or sell the unprotected ears as early as possible.

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